



**National  
Safety  
Council**

**Data Sheet  
I-700-Rev 86**

## Hydrogen Usage in the Laboratory

**G**ASEOUS HYDROGEN — its transportation, storage, handling, and use — has been the subject of many guidelines, rules, and procedures. The recommendations contained in this data sheet are quite general and are intended to be used in conjunction with company and government rules and regulations that are applicable to a specific subdivision of an industry.

### Properties, Hazards, and Safety Precautions

2. Gaseous hydrogen is an extremely flammable and explosive element in an air or oxygen atmosphere. The explosive range in air is from 4.0-75 vol % of hydrogen. The explosive range of hydrogen with other diluent gases varies, and the hazards must be evaluated before using such mixtures in the presence of oxygen. Hydrogen can be detonated over the range of 20-60% by volume in air, given good mixing, confinement, and ignition source. This range is for a low-energy ignition source. Hydrogen-air mixtures have been known to detonate down to 13.8% hydrogen with a sufficiently strong source.

3. In order for a hydrogen fire or explosion to take place, (a) hydrogen, (b) an oxidant, usually air, and (c) an ignition source must be present simultaneously. Elimination or control of any one of these three can reduce the possibility of an explosion. Some of the properties of

hydrogen that have a direct relationship to safety are as follows:

- Hydrogen has a low ignition energy requirement (0.00002 J, minimum), which means it can be ignited by an almost imperceptible spark or static electricity discharge built up on a person.
- Hydrogen gas has a specific gravity of 0.07 (air = 1) and has a high diffusion coefficient because of its low molecular weight.
- Burning hydrogen produces an intensely hot, nonluminous flame unless colored by impurities. Because of this, it is often difficult to judge the boundaries of a hydrogen conflagration. (A check for the flame can be made with tissue paper on a stick, by using a straw or natural fiber broom, or by looking at the sun shadow of a burning vent stack.)
- Hydrogen is colorless, tasteless, and odorless.

4. Design and rate any electronic or electrical equipment, including lights, motors, plugs, electrical receptacles, and support wiring, for service with hydrogen. When an ignitable level of hydrogen may frequently exist, electrical equipment should comply with the requirements of the *National Electrical Code*, NFPA 70, for class I, division 1, group B locations. When an ignitable level of hydrogen may exist only occasionally, electrical equipment

should comply with the *National Electrical Code* for class I, division 2, group B locations. Consult NFPA 497, *Recommended Practice for Classification of Class I Hazardous Locations for Electrical Installations in Chemical Plants-1975*, as a reference.

5. When Underwriters Laboratory (UL)-approved electrical or electronic hardware for class I, group B locations is not available, follow the *Standard for Purged and Pressurized Enclosures for Electrical Equipment in Hazardous (Classified) Locations-1982*, NFPA 496. Alternately, it may be possible to use intrinsically safe systems or equipment; however, intrinsically safe equipment must be certified to meet all requirements of NFPA 493, *Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1 Hazardous Locations-1978*. For hydrogen service, considering the very low ignition energy of hydrogen, carefully evaluate the use of truly intrinsically safe systems or equipment.

6. Confined spaces containing hydrogen piping should be inerted or be sleeved and vented to a safe location to prevent the buildup of explosive concentrations of hydrogen. The potential for asphyxiation due to the inerting gas must be considered. The use of ventilated utility chases can minimize the fire potential and the need for an inerting gas.

444 North Michigan Avenue  
Chicago, Illinois 60611  
312-527-4800

7. Access of hydrogen-air mixtures to high temperature surfaces must be carefully controlled, because its ignition temperature is 585 C (1,085 F).

8. Because it may be impossible to eliminate all ignition sources, place emphasis on preventing the formation of combustible atmospheres by maximum use of gas confinement; ventilate enclosed spaces where leakage is possible, such as laboratory hoods and ceiling areas.

9. Provide local exhaust ventilation to vent gases adequately in case of a failure in the system. Gas concentration in a ventilation system should not exceed 25% of the lower explosive limit of the gas mixture.

10. After the gas system is set up for use, all valves and connections should be leak-tested, using a soap solution or a commercial leak-detecting solution to make sure that the system is gastight. Never use a flame to detect hydrogen gas leaks. Before hydrogen use, purge air from a hydrogen piping system with an inert gas.

11. Evaluate the need for continuous automatic hydrogen monitoring equipment, with strategically located sampling points directly above high-risk apparatus and immediately beneath the ceiling, and provide, as needed. Here are two suggestions:

- Calibrate monitoring equipment to provide for short response time and detection of 25% of the lower explosive limits. An audible alarm should sound at the sample point location as well as at the control room or similar central panel that indicates the location of the hazardous condition. Loss of ventilation shall sound the alarm in the control room. The readout device or control unit must never be located in the hazard area.
- Many factors contribute to the decision as to need for and type of hydrogen detection systems. These factors include volume of gas, ventilation, type of enclosure, and possibility of mixture with oxidants. The safety review should include determination of the need for the detection system.

12. Do not flare the exhaust from

small hydrogen-atmosphere furnaces in the laboratory. Use a minimum hydrogen mix with an inert gas balance, and exhaust the effluent gases through a laboratory fume hood with a fail-safe gas shutdown system.

13. The exhaust from large hydrogen-atmosphere furnaces must empty to the outside of the building through proper ductwork or hoods. Add auxiliary air to the duct to assure that the concentration level is < 25% of the lower explosive limit or vent 100% hydrogen until mixing outside of the building. Purging with inert gas or a vacuum should be done both before and after introducing hydrogen.

14. Adequately ventilate the manifold area of hydrogen systems, and provide the system with electrical bonding and grounding.

15. Pilot plants must comply with federal regulations (OSHA Act 29 CFR 1910.103), NFPA-50A, and ANSI-B31.1 standards that limit the total volume of hydrogen in each system/building area.

#### Containers

16. Currently, the Bureau of Explosives Tariff No. BOE-6000-A specifies requirements for all compressed gas cylinders. Specifications 3A or 3AA are used for hydrogen gas. Cylinder valve outlets should follow the Compressed Gas Association (CGA) Standards, using a CGA 350 fitting with left hand thread.

#### Storage

17. Stringently follow the safe handling rules for compressed gas cylinders when handling hydrogen. Store cylinders in well-ventilated, protected, dry locations, and place away from combustible materials. Separate from oxidizing gases by at least 20 ft (6.1 m) or by a ½-hour fire-resistive barrier. Prominently indicate the presence of hydrogen in storage areas.

18. Identify cylinders and lines so that there is no mistake whenever adjusting flow or changing cylinders. Connections should be accessible to allow for monitoring of leaks.

#### Posting and barriers

19. In areas where hydrogen is

used, including areas where post the warnings **HYDROGEN — FLAMMABLE** followed by appropriate instructions, such as **NO SMOKING** and **NO OPEN FLAMES**.

20. In smaller facilities, such as individual laboratories, access to hydrogen use areas may be controlled using appropriate warning signs and possibly adding flashing lights. Such devices should be displayed only when potential hazards from hydrogen actually exist.

#### Protective equipment

21. Personal protective equipment may be required, depending on the hazard involved. Some of the most common types are listed here.

- Wear safety glasses as minimum protection in any hydrogen experiment or handling operation. Use other eye and face protection, such as face shields with safety glasses and goggles, as specified by the safety officer.
- Wear safety shoes in all operations.

#### Training

22. Thoroughly train and indoctrinate personnel using equipment that uses or contains hydrogen before operating the equipment. The training should include properties and hazards of hydrogen and all procedures for normal operations and for emergencies.

#### Operating Procedures

23. Designate a "hydrogen safety officer."

24. Checklists will facilitate the orderly execution of procedures. Deviations from established procedures must be appropriately documented and approved by the hydrogen safety officer.

25. Conduct and document pre-operation safety reviews for all new or extensively modified experiments or processes involving the use of hydrogen. When the degree of hazard is significant, at least one person, who is independent of the programmatic pressures involved in the experiment, should participate in this review team. The review should include the following elements:

- The experimenter should pre-

pare a written description of the experiment or process, covering equipment and procedures, and analysis of the hazards and the measures to minimize them.

- The independent review person or group should study the experimenter's plans, recommend additional precautions, if necessary, and conditionally approve commencement of operations or an operational start-up for evaluation. The recommendations of the review person or group shall be binding on the experimenter unless relieved by the officer-in-charge. The size of the review group, its range of expertise, and the formality of procedure and documentation should be appropriate for the magnitude of the hazard in the anticipated experiment. All personnel involved in the actual performance of the experiment should be present during the evaluation review before the operational start-up. Make documentation of all reviews readily available to all operators during the experiment.

26. The presence of unnecessary personnel in areas where hydrogen is used or generated should be strictly forbidden, especially during times of active operation.

27. All gaseous hydrogen systems should be thoroughly leak-tested with an inert gas such as nitrogen. Test under operating temperatures and pressures similar to those intended for actual use, because leaks may occur as a result of differential contraction of the parts of the equipment when cooled or as a result of differential expansion of parts when exposed to high pressures.

28. To avoid propagating a flash fire that might accidentally occur when handling hydrogen, keep combustible materials in the area to an absolute minimum. Paper, rags, unprotected wood, combustible liquids, dangerous gases such as oxygen, acetylene, propane, and toxic materials should be removed from the area unless essential to the operation.

- Protective measures for combustible materials that must be kept in the area may consist of enclosure in noncombustible

cases or the use of water spray or deluge systems.

- Use flame arresters specifically designed for hydrogen systems where the potential of flashback exists.

29. Static electricity can cause a spark to jump between two pieces of equipment or from a person to a piece of equipment. Some of the precautions to reduce static hazards include: humidification; bonding supply vessels and experimental apparatus to a common potential before any transfer is attempted; ionization; and provisions for proper grounding (by touching a water pipe, as an example) of all users to discharge any static before handling equipment.

30. Leaking gas fires should not necessarily be extinguished promptly. Inerting the system first is an important emergency consideration. Then and only then should the hydrogen be turned off and the system depressurized; adjacent equipment should be cooled with water-fog nozzles. System shutoff valves should be readily accessible and prominently marked.

31. Hydrogen discharging from a system has been known to self-ignite. For this reason, do not crack a valve of a hydrogen container to remove dust or dirt from fittings.

32. In areas where hydrogen is used or stored, whenever construction requires the use of flames, high-temperature equipment, or spark-producing tools, hot work must be authorized and supervised by trained personnel designated by management.

33. Because the procedure for approval of hot work involves checking the area with an explosion meter (flammable gas meter) and ordinary explosion meters are not authorized for use in a hydrogen/air atmosphere, use special instruments rated for this service.

34. Provide ventilation in spaces where hydrogen is used or generated to prevent hazardous buildup.

35. Some general rules follow for using hydrogen gas cylinders in laboratory buildings where they are not permanently set up:

- Limit cylinders to smallest practical size;

- Manifold user equipment to limit the number of cylinders required;
- Use flow-restricting orifices or flow-limiting automatic valves, in line;
- Make sure that there is adequate dilution/ventilation and that fire and electrical code requirements are met;
- Consider locating a hydrogen manifold outside (open air) the laboratory and piping in the gas at minimum usable pressure, and install a relief valve set at 10% above operating pressure, and vent to the outside.

36. Metals with strength to contain the pressure involved may be used at normal temperatures, if they are not susceptible to hydrogen embrittlement, eg, austenitic stainless steels, corrosion-resistant alloys (Monel), aluminum, or copper. However, copper can work-harden and fail if the lines are not secure. Use braided flexible pigtailed of appropriate stainless steel between regulator and delivery manifold. Cast iron and martensitic stainless (such as type 403) are not satisfactory for use with hydrogen.

37. Preplan fire fighting for each installation for the local situation. Include considerations for evacuating, getting upwind, valve closure, moving containers, and others. It may be necessary to rely on professional help (outside fire companies). It is crucial to meet with them ahead of time, and familiarize them with your operation, your emergency personnel, and your basic emergency plan.

#### ACKNOWLEDGEMENT

This data sheet was prepared by the Research and Development Section of the Industrial Division of the National Safety Council, 444 N. Michigan Ave, Chicago IL 60611.

#### BIBLIOGRAPHY

Compressed Gas Association, 1235 Jefferson Davis Highway, Arlington, VA 22202.

-Commodity Specification for Hydrogen, G-5.3

-American National, Canadian, and Compressed Gas Association Standard, Compressed Gas Cylinder Valve Outlet and Inlet Connections, V-1 (ANSI B57.7, CGA B96).

-Handbook of Compressed Gases.  
-Hydrogen, G-5.

"Hazardous Materials Regulations." Title 49—Transportation, *Code of Federal Regulations, Chapter 1, subchapter C*, parts 171-179. (Available from the U S Government Printing Office, Washington, DC 20402.) Also issued as AAR Bureau of Explosives Tariff No. BOE-6000-A, by Thomas A. Phemister, Agent, Association of American Railroads, 1920 L St. NW, Washington, DC 20036.

Braker W, Mossman A: *Matheson Gas Data Book*, 6th ed. East Rutherford, NJ, Matheson, 1980.

National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

-Standard for Gaseous Hydrogen Systems at Consumer Sites, NFPA 50, 1984.

-Fire Protection Handbook, 16th ed., 1986.

-Recommended Practice for Classification of Class 1, Hazardous Locations for Electrical Installations in Chemical Plants, NFPA 497.

-Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division I Hazardous Locations, NFPA 493.

-Standard for Purged and Pressurized Enclosures for Electrical Equipment in Hazardous Locations -1982, NFPA 496.

-National Electrical Code-1984, NFPA 70-84.

"Welding and cutting," in *Accident Prevention Manual for Industrial Operation*, vol. 2, *Engineering and Technology*, 8th ed. Chicago, National Safety Council, 1980, chapter 13, pp 479-507.

"Stainless steel in high pressure hydrogen use," in Peckner D, Bernstein IM: *Handbook of Stainless Steels*. New York, McGraw-Hill Book Co, chapter 46, 1977.

U S General Services Administration National Archives and Records Service, Office of the Federal Register, Washington, DC. Available through U S Government Printing Office, Washington, DC 20402.

-"Hydrogen." Title 29—"Labor," *Code of Federal Regulations* chapter XVII, 1910, section 1910.103.

Factory Mutual Engineering Corporation, Norwood, MA 02062

-Factory Mutual Loss Prevention Data Sheet 6-10 *Process Furnaces*, 1976.

Bureau of Mines (BOM) U S Department of Interior, Washington, DC.

-Zabetakis, Michael G.: BOM Bulletin No. 627, *Flammability Characteristics of Combustible Gases and Vapors*, 1965.

Lewis B, Von Elbe G: *Combustion, Flames and Explosions of Gases*, 2nd ed. New York, Academic Press, 1961.

---

An Alphabetical Index of all Industrial Safety Data Sheets (Stock No. 123.09) is available from the Council on request.

---



---

COPYRIGHT © 1986 NATIONAL SAFETY COUNCIL  
ALL RIGHTS RESERVED

---

While the information and recommendations contained in this publication have been compiled from sources believed to be reliable, the National Safety Council makes no guaranty as to, and assumes no responsibility for, the correctness, sufficiency or completeness of such information or recommendations. Other or additional safety measures may be required under particular circumstances.

---